WHO'S WHO?

EVOLUTION AND BATESIAN MIMICRY

Topics Covered:

- **The principles of evolution by natural selection**
- **The importance of Bates', Wallace's and Darwin's contributions to science**
- **How genetic and environmental factors influence variation**
- **Genetic linkage**

Background information about Henry Walter Bates, 1825 – 1896

The Victorian era was a period of great expansion and development of the British Empire and a golden period of adventure and exploration. Reports and specimens sent back to England from exotic places such as South America, Africa and the Far East fired the enthusiasm of a generation of great young naturalists. In 1844 two young men, aged 19 and 21, who had both read and been inspired by Darwin's book *The Voyage of the Beagle*, met by chance in Leicester Public Library. They became friends and soon decided to set off on a voyage of discovery up the Amazon River in South America. They were Alfred Russel Wallace and Henry Walter Bates.

Bates was born in Leicester, the son of a stocking factory owner. As a boy he became passionately interested in insects and published his first scientific paper (on beetles) at the age of 17! He was trapped in a boring office job in his father's firm. Bates and Wallace planned to fund their expedition by collecting butterflies prized by collectors in Europe. In 1848 they set sail for the city of Pará (now Belém) on the coast of Brazil, where the mighty River Amazon finally meets the Atlantic Ocean.

© Dennis Taylor

Stuck in a boring job, what Bates really wanted to do was collect butterflies

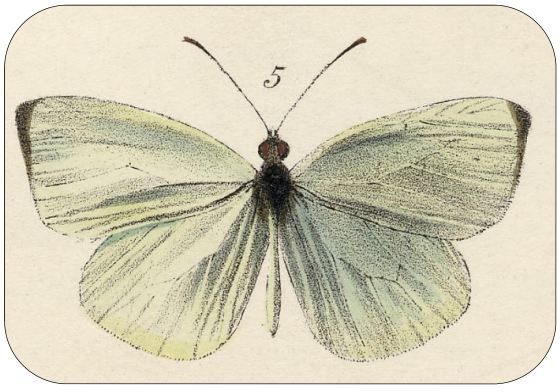
They parted after a year and Wallace returned to England in 1852. Unfortunately, his ship caught fire on the journey and most of his collection was destroyed. Undeterred, Wallace set off in the opposite direction and travelled through the 'East Indies', now known as Indonesia and Malaysia, from 1854 to 1862.

Meanwhile, Bates was to spend a total of eleven years in 'Amazonia', a vast network of largely unexplored major rivers and their tributaries set in the world's largest area of tropical rain forest. By the time he returned in November 1859 he had sent back over 14000 specimens, mainly insects, over half of which were newly recorded species.

The year before Bates' return, Wallace, who was still collecting in the East Indies, sent a paper to Darwin outlining a theory he had developed to try to explain how evolution of living things could occur by a process of natural selection. Darwin had independently arrived at the same theory. It was agreed that they submit a joint paper to the Linnean Society in London in 1858. Darwin's famous book *On The Origin of Species by Natural Selection*, which gave a detailed account of the theory and the evidence for it, was published a year later in June 1859. Five months later, in November 1859, Bates was back in England with his own collection and observations and had already been thinking along similar lines to Darwin and Wallace. As soon as he got back, he read Darwin's book and was immediately struck by how well it could explain some of his own observations. In particular, it seemed to be able to explain a phenomenon he had observed among butterflies which he described as **mimicry**.

Batesian mimicry

One of the most common types of butterfly that Bates observed in the forests of Amazonia belonged to the family now known as Nymphalidae (we'll refer to it as Family 'N' for short). They have characteristic wide, elongated wings and a slowly flapping flight. They are brightly coloured and patterned (see page 3). However, when Bates examined captured specimens in detail, he discovered that these butterflies were not always what they seemed. Characteristics such as the pattern of 'veins' on the wings showed that a few belonged to a completely different family, the Pieridae ('P' for short). Typically, members of this family are white or yellow and have different-shaped wings (the wings are not elongated), as you can see in the image below.



Family P *Dismorphia nehemia*

Family N butterflies produce a foul smell and are avoided by insectivorous birds. Family P butterflies are perfectly edible, but Bates noted that birds couldn't tell the difference between them and members of Family N when the butterflies were in flight. Later research has shown that Family N butterflies contain chemicals which make them distasteful to insectivorous birds - the birds vomit if they make the mistake of eating one! They get the chemicals from their caterpillar stage and the caterpillars get them from the plants they eat.

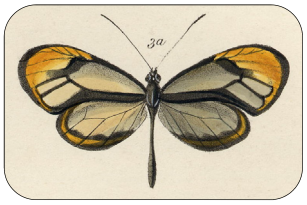
Bates had discovered what we now refer to as **Batesian mimicry**. In Batesian mimicry a palatable species mimics an unpalatable one. Palatable means it's good to eat. Unpalatable ones are presumably distasteful. This mimicry was one of many examples he discovered among butterflies. He also discovered examples amongst birds and reptiles. We now refer to the unpalatable species as the '**model**' and the species which imitates it as the '**mimic**'.

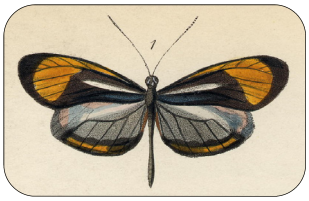
WHO'S WHO?

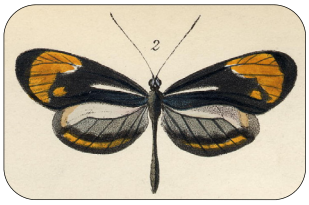
In 1862, Bates published a famous paper in *The Transactions of the Linnean Society* which described his findings. The diagrams of butterflies in this worksheet are taken from that paper. In 1863 Bates also published what is generally agreed to be one of the finest travel books ever written, *The Naturalist on the River Amazons*.

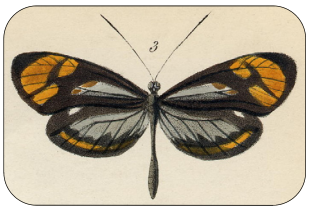
MODELS Family N
Five different species of the genus *Ithonia* are shown

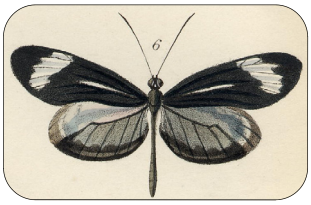
MIMICS Family P
Butterflies shown are all the same species, *Dismorphia theonoe*

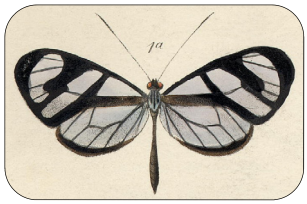


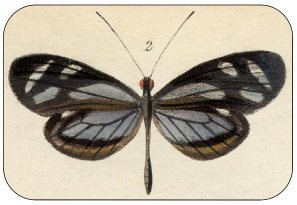












Q1 Of the two families, 'N' and 'P', mentioned in the introduction above, which contains the 'model' butterflies and which the 'mimics'? [1]

Q2 **(a)** What is the advantage gained by the mimic? [1]

(b) Explain how this advantage is gained. [2]

(c) Suggest a possible disadvantage for the model. [1]

Bates observed that the mimics were always "very much fewer in individuals" than the models they imitate – "they cannot be more than as 1 to 1000…".

Q3 Explain why it would be a disadvantage for the mimic to be as common as the model. [2]

Q4 State two characteristics of mimics that would have enabled Bates to decide whether a butterfly was a model or a mimic. [2]

Page 3 shows examples of family N and family P. The members of family P shown are all the same species, *Dismorphia theonoe*. Page 3 also shows that a species such as *Dismorphia theonoe*, which is a mimic, may have many different forms. The species is described as **polymorphic**. Not surprisingly, it was very difficult for Bates and other naturalists to decide whether the different forms were different species or different varieties of the same species. As Bates said in his paper, "It may be asked, how can we know they are all varieties… of one species?"

Q5 How could a biologist determine whether two different forms were in fact the same species? [2]

Q6 **(a)** Humans can be described as **dimorphic**. Why is this? [1]

(b) State whether a dimorphic characteristic (phenotype) would be an example of continuous or discontinuous variation. [1]

Q7 Bates believed Darwin's theory of natural selection could explain mimicry. What would Bates have said was the **selective agent** responsible for the evolution of mimicry? [2]

Q8 According to the theory of natural selection, the better adapted individuals of a species are more likely to survive. Suggest another possible explanation (other than that given by Bates) for the fact that mimics and models resemble one another. [1]

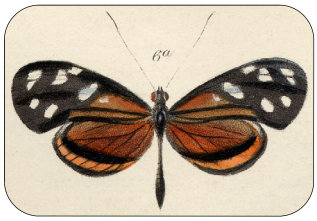
Q9 The caterpillars of mimics do not mimic the caterpillars of models. Suggest two possible reasons why this is the case. [2]

Darwin hailed Batesian mimicry as "a most beautiful proof of natural selection". Butterflies in family P tend to live in open grassland. As mentioned in the introduction, they tend to be white or yellow in colour and their wings are not elongated (see picture on page 2). The members of family P that Bates found in the forests of Amazonia were all mimics. However, the more butterflies that Bates collected, the more intermediate forms he discovered, even though these were very rare (only one or very few found). These intermediate forms do not usually imitate any other butterflies. Some of them were shown in his paper of 1862 and are shown below. The top butterfly in Family P (butterfly 6) seems to mimic a member of family N (*Ithonia illinissa*).

Q10 Explain how Darwin's theory of natural selection can be used to explain the origin of the mimics and the existence of forms that are intermediate between the original members of Family P and the mimics. [5]

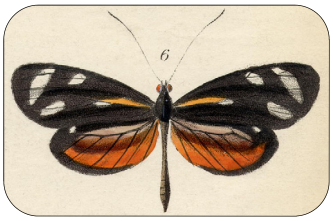
Family N

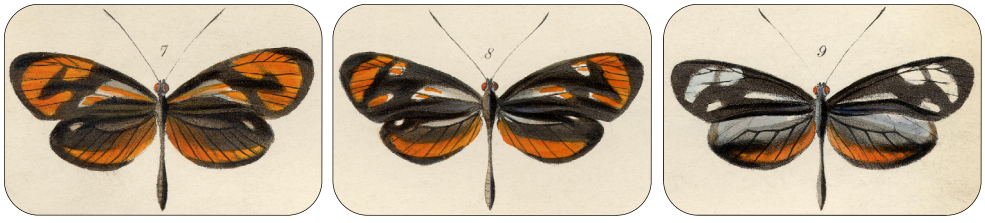
A member of family N (*Ithonia illinissa*)



Family P

Six members of family P showing rare intermediate forms of *Dismorphia theonoe*





Q11 Mimics are not **exact** copies of the models (see page 3). Suggest **two** reasons why not. [2]

The image below shows the butterfly species *Papilio dardanus*, a swallowtail butterfly which belongs to the family Papilionidae. It mimics three different species of the family Danaidae. In *Papilio* the different morphs (forms) are controlled by a group of tightly linked* genes (a 'supergene').

© Dave Rogers

**note for those who have not studied linkage*
All the genes on a given chromosome are said to be 'linked'. This is because they tend to stay together during the process of meiosis, when whole chromosomes segregate. The closer they are together, i.e. the more tightly they are linked, the more likely they are to stay on the same chromosome during meiosis.

Q12 (a) Define the term linkage. [1]

(b) Linkage affects the amount of variation shown by the morphs. State what effect linkage has on variation. [1]

(c) Suggest why it is an advantage for the genes of a given morph to be tightly linked. [2]

(d) At what stage in the life cycle of a butterfly does meiosis occur? [1]

Bates observed that when butterflies mate they seem to be very selective in choosing a partner with a very similar colour pattern. Selective mating like this influences speciation.

Q13 (a) Explain one possible **advantage** and one possible **disadvantage** of this behaviour. [4]

(b) Define the term 'speciation'. [1]

(c) What effect would selective mating have on speciation? Explain your answer. [2]

Another type of mimicry, known as Müllerian mimicry, was identified by the German biologist Fritz Müller in 1878. In this case, two or more **model** species evolve to resemble each other. The models show warning colouration which deters predators from eating them – they may be unpalatable, poisonous, have a sting, etc..

For example, the yellow and black striped warning pattern is common to several different species of stinging wasps. Another example is the butterfly *Heliconius*, found in South and Central America. *Heliconius erato* and *Heliconius melpomene* are both distasteful to birds and they mimic each other. At least eleven different warning patterns are found in different regions, but in any one region the two species share the same pattern.

© Chris Perrett www.naturesart.co.uk

A butterfly of the genus *Heliconius*

Q14 (a) Why is it important that, in a given region, the pattern for *H. erato* is the same as that for *H. melpomene*? [1]

(b) Explain the evolutionary advantage gained by two different distasteful species mimicking each other.* [1]

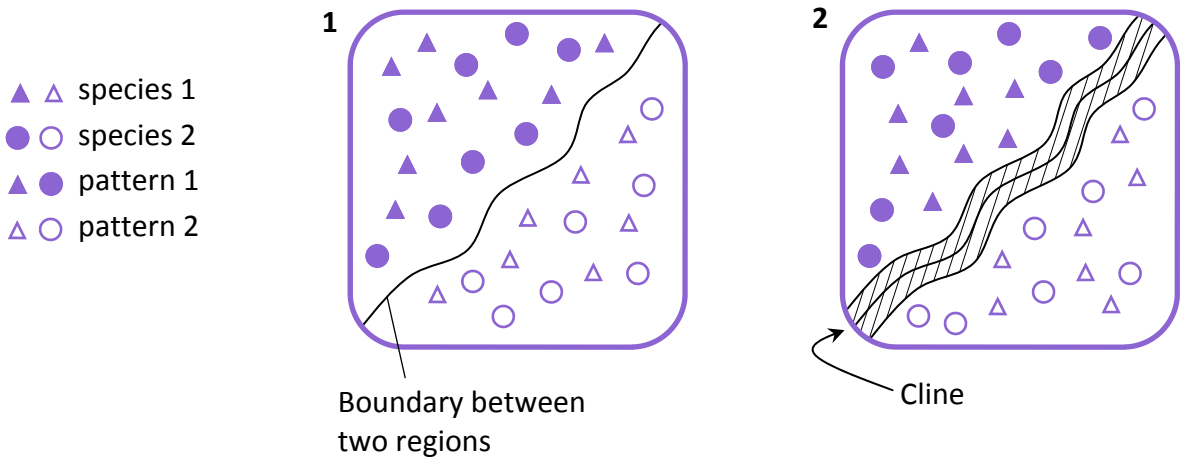
(c) Some harmless insects, such as certain hoverflies, mimic wasps. What type of mimicry is this? [1]

© Dennis Taylor

A hoverfly mimicking a wasp

* **N.B.** The two species of *Heliconius* can be strikingly similar. They can be compared by looking them up in the Linnaean collection under their original names that Linnaeus used, namely *Papilio erato* and *Papilio melpomene*. Access the website of the Linnean Collections Online using the web address www.linnean-online.org. Select 'Insects' from the top menu and follow the links to the appropriate specimens.

Diagram 1, below, shows an imaginary situation similar to *Heliconius* in question 15.



There are two species, but only two pattern types. In this imaginary situation two regions with different pattern types meet at a common boundary. In such a situation there is a possibility of interbreeding (hybridisation) between butterflies from the two regions. This results in a zone called a **cline** where hybrid offspring are found (Diagram 2).

Q15 (a) Explain what is meant by a hybrid. [1]

(b) What possible hybridisations are **most** likely to take place in this imaginary example? [2]

(c) Suggest two factors which will determine the width of the cline. Explain your answer. [4]

(d) The colour pattern is controlled by three tightly linked genes in *H. erato* and by four tightly linked genes in *H. melpomene*. Each gene has a number of alleles. If the colour pattern in species 1 in the diagram above were controlled by one gene with three alleles, what would be the maximum number of colour patterns that could appear in species 1 in the cline? [1]

(e) Distinguish between the terms 'allele' and 'gene'. [2]

Point for discussion:

In a small group, discuss whether you think it would be an advantage if the birds were killed by the toxins contained in the butterflies.